

**Before the  
FEDERAL COMMUNICATIONS COMMISSION  
Washington, DC 20554**

In the Matter of	)	
	)	
Promoting Investment in the 3550-3700	)	GN Docket No. 17-258
MHz Band	)	
	)	

**REPLY COMMENTS OF CTIA**

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CTIA submits these reply comments in response to the Notice of Proposed Rulemaking (“*Notice*”) issued by the Federal Communications Commission (“Commission”) in the above-captioned proceeding.<sup>1</sup>

**I. INTRODUCTION AND SUMMARY.**

The initial comments in response to the *Notice* demonstrate the importance of fostering a framework in the 3550-3700 MHz band (“3.5 GHz Band”) that will support a broad group of stakeholders and use cases for the Citizens Broadband Radio Service (“CBRS”). Many commenters recognize that the targeted modifications in the *Notice* will better ensure that the full potential of this band is realized, including the important role it will play in providing capacity for 4G LTE networks and in the development of 5G networks. Indeed, the record makes clear that this band has been targeted as a key band for 5G deployments in countries across the globe, further highlighting the importance of crafting rules that will promote investment and facilitate U.S. leadership in the 5G ecosystem.

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<sup>1</sup> *Promoting Investment in the 3550-3700 MHz Band*, Notice of Proposed Rulemaking, 32 FCC Rcd 8071 (2017) (“*Notice*”). Unless otherwise noted, comments referenced herein were filed on or about December 28, 2017 in GN Docket No. 17-258.

The changes identified here will promote long-term investment in the 3.5 GHz Band by bringing more predictability to Priority Access Licenses (“PALs”) and supporting more use cases. They will not diminish investments already made in the three-tier framework. And they will not affect General Authorized Access (“GAA”) operations. The record confirms that if the Commission adopts these changes, it will encourage a broad range of firms to invest in CBRS equipment and deployment – benefiting the CBRS ecosystem as a whole, including PAL and GAA users in urban and rural locations. On the other hand, shorter license terms, the absence of a presumption of renewability of licenses, and small geographic license areas are among the factors likely to diminish the market value for PALs by as much as 50 to 95 percent relative to the value of similar licensed spectrum. CTIA therefore urges the Commission to:

- Extend the PAL term to 10 years with an expectation of renewal and decline to adopt specific performance requirements;
- License PALs on a Partial Economic Area (“PEA”) basis;
- Facilitate the secondary market by permitting partitioning and disaggregation of PALs;
- Eliminate the requirement for public disclosure of certain Citizens Broadband Radio Service Device (“CBSD”) registration information;
- Revise the out-of-band emissions (“OOBE”) limits to enable wider channels, consistent with the Qualcomm proposal; and
- Eliminate the policy that prevents PAL assignment when there is only one applicant in a given license area and the policy that makes available fewer PALs than bidders seek.

By taking these steps, the Commission can better promote investment in the licensed portion of this much needed spectrum band without adversely affecting incumbents or users of the GAA tier. And changes to the PAL rules will generate robust investment that will encourage innovation and expanded equipment development for the benefit of PAL holders and GAA users alike.

## **II. THE RECORD SHOWS THAT THE PROPOSED CHANGES TO THE CBRS RULES WILL FUEL INVESTMENT, NOT STIFLE IT.**

The modest changes to the PAL framework identified here will foster significant investment for a wide variety of use cases, including 5G; create new avenues for micro-targeted secondary market transactions; and continue to promote robust access to the 3.5 GHz Band via the GAA tier and the use-or-share policy for GAA access to PAL spectrum. Indeed, commenters who are heavily engaging in industry standards bodies, developing products, and conducting trials support moderate changes to advance the CBRS ecosystem.<sup>2</sup>

Commenters point out that the 3.5 GHz Band is fast becoming a crucial band for next-generation wireless services across the globe.<sup>3</sup> As Ericsson notes, “mid-band spectrum [is] a crucial piece of the puzzle for meeting exploding demand for bandwidth in existing networks and providing capabilities needed for small cell deployment, wide-area networks, and next-generation services.”<sup>4</sup> U.S. wireless carriers are expected to invest \$275 billion to win the global race to next-generation 5G networks, creating three million new jobs and adding \$500 billion to our economy.<sup>5</sup> Exploiting that significant economic opportunity is dependent on the adoption of rules that will promote investment in key spectrum opportunities like the 3.5 GHz Band. Bringing the 3.5 GHz Band rules into alignment with other successful bands, while retaining its innovative sharing structure, offers significant potential to drive this investment.

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<sup>2</sup> See, e.g., Ericsson Comments at 5; Verizon Comments at 3, 5; Nokia Comments at 2-3.

<sup>3</sup> Notice at 8072-73 ¶ 3.

<sup>4</sup> Ericsson Comments at 1.

<sup>5</sup> *Smart Cities: How 5G Can Help Municipalities Become Vibrant Smart Cities*, ACCENTURE STRATEGY, at 3 (2017), <https://www.ctia.org/docs/default-source/default-document-library/how-5g-can-help-municipalities-become-vibrant-smart-cities-accenture.pdf>.

The Commission's former Chief Economist Michelle Connolly, in an economic analysis attached to this filing, states:

While very local uses may have been at the forefront in the 2015 *First Report and Order*, this is not a natural limitation to the possible use of the CBRS band. Economically, the CBRS auction design should not *ex-ante* preclude the use of other possible technologies such as 5G. However, the 2015 rules potentially preclude much participation in the PAL auctions by increasing exposure risks, total auction and secondary market transactions costs, and uncertainty over the expected time frame under which a license holder can receive protected access to spectrum over a larger service area.<sup>6</sup>

As one commenter noted “[t]o lead the world in 5G,” the Commission’s rules must “foster, not impede, a wide range of services and uses.”<sup>7</sup> As discussed below, the proposed changes will create greater certainty to promote investment, spur innovation, and advance U.S. leadership in 5G. Indeed as Professor Connolly concludes, the “propose[d] changes [] will unambiguously increase the economic value of and total investment in the CBRS band.”<sup>8</sup>

**A. Contrary to Some Claims, the Proposed Changes Will Not Strand Investments in the CBRS Ecosystem.**

CTIA appreciates wireless Internet service providers’ (“WISPs”) recognition that auctions and exclusive-use licensing serve an important role in spectrum policy, but claims by some WISPs that changes to the PAL framework will strand investment and eliminate opportunity in the 3.5 GHz Band fail to account for the CBRS framework’s novel three-tier spectrum access approach. In particular, many WISPs report that they purchased 3650-3700 MHz wireless broadband network equipment for use today, with an eye toward extending use

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<sup>6</sup> See Attachment A, Michelle Connolly, PH.D., *Impact of Proposed Changes to Improve Investment in the 3550-3700 MHz Band* at 15-16 (January 29, 2018) (“Connolly Analysis”).

<sup>7</sup> Mobile Future Comments at 3-5.

<sup>8</sup> Connolly Analysis at 23.

across the 3.5 GHz Band once CBRS becomes operational. They assert that without PALs available in census tracts on three-year terms, their purchases will be a wasted investment.<sup>9</sup>

First, to the extent that WISPs pre-positioned investment in network equipment based on the assumption that they would win PALs at auction, that is a market risk borne by any entity seeking exclusive-use, auctioned spectrum. Second, although some WISPs claim that they will be foreclosed from the 3.5 GHz Band because larger stakeholders will out-bid them,<sup>10</sup> the results of the 600 MHz incentive auction belie this view, as 38 of the 50 winning bidders were small or rural businesses.<sup>11</sup> WISPs argue further it would be particularly unfair if larger stakeholders win the PALs because they will not deploy in the hard-to-reach, rural areas that these WISPs serve.<sup>12</sup> However, even *if* that were true, then the CBRS's novel use-or-share scheme would provide these WISPs with GAA access to the entirety of the 150 megahertz in the 3.5 GHz Band. These WISPs, who operate today in unlicensed and non-exclusive licensed bands, would thus gain access to the full 3.5 GHz Band at no cost.

Alternatively, should others win PALs (regardless of the PAL's geographic area) and deploy in the WISPs' service areas, these WISPs would still have access to 80 megahertz of GAA spectrum – more spectrum than the 3650-3700 MHz band spectrum that they are operating

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<sup>9</sup> See, e.g., Byhalia.net, LLC. Comments at 1; GigaBeam Networks Comments at 1; All Points Comments at 1-2; Vertical Broadband Comments at 3; Vivint Comments at 2; Southern Linc Comments at 1.

<sup>10</sup> See, e.g., Aristotle Unified Communications Comments at 1; Dynamic Spectrum Alliance Comments at 13-14.

<sup>11</sup> See *Incentive Auction Closing and Channel Reassignment Public Notice the Broadcast Television Incentive Auction Closes; Reverse Auction and Forward Auction Results Announced; Final TV Band Channel Assignments Announced; Post-Auction Deadlines Announced*, Public Notice, 32 FCC Rcd 2786, 2823, Appendix B (2017).

<sup>12</sup> *Id.*

their “at risk” equipment in today.<sup>13</sup> Thus, arguments that the proposed changes will strand investment in equipment fail to recognize the innovative three-tier design and the use-or-share spectrum approach. WISPs’ investment in network equipment prior to auction will not become wasted.

**B. The Current PAL Framework, with Three-Year Terms, No Renewal, and Census Tract Licensing, Risks Undermining Broad Investment in the CBRS Ecosystem.**

As currently structured, the licensing rules do not provide the necessary level of certainty that is essential to invest in a new band, in networks, and in seeding the marketplace with CBRS consumer devices. In contrast, the proposed modifications to the 3.5 GHz Band will support investment in the 3.5 GHz CBRS ecosystem, the rapid deployment of innovative networks and services in urban and rural areas, and U.S. leadership in 5G.

Professor Connolly finds that the existing PAL framework creates significant uncertainties that risk investment in the 3.5 GHz Band.<sup>14</sup> Professor Connolly notes that “uncertainty reduces investment” and that the current rules – including the license duration (both term and renewal expectancy) and the geographic area size of licenses – create significant uncertainties for firms considering investment in PALs and the 3.5 GHz Band. She observes, for example:

Three-year license terms (even with the option to petition for two consecutive three-year terms in the *first* application window) provide little time for returns to investment given the infrastructure heavy nature of this industry. Combined with the 2015 presumption of no renewal, license valuation, investment, and the subsequent

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<sup>13</sup> *Amendment of the Commission’s Rules with Regard to Commercial Operations in 3550-3650 MHz Band*, Report and Order and Second Further Notice of Proposed Rulemaking, 30 FCC Rcd 3959, 3964 ¶ 4 (2015).

<sup>14</sup> Connolly Analysis at 2.



value to consumers would be severely diminished relative to the more standard ten-year FCC license terms with a presumption of renewal.<sup>15</sup>

Further, Professor Connolly notes that census tract licensing creates numerous inefficiencies that place a significant drag on investment in the 3.5 GHz Band. Among other concerns, she finds that “[i]t is highly likely that the population level of a census tract is not sufficiently large to take advantage of possible economies of scale for many of the potential uses of the 3.5 GHz band. This is particularly true for the potential deployment of 5G.”<sup>16</sup>

Modifying the licensing rules as identified here will trigger investment in PALs that will benefit PAL and GAA users alike through innovation in the band and expanded equipment development efforts. “Without sufficient licensee investment, a robust equipment ecosystem for unlicensed use is less likely to develop in the 3.5 GHz band.”<sup>17</sup> Promoting licensee investment thus advances the entire CBRS ecosystem.

### **III. COMMENTERS EMPHASIZE THAT 10-YEAR PAL TERMS AND RENEWAL EXPECTANCY ARE KEY ELEMENTS TO FOSTER INVESTMENT AND INNOVATION IN THE 3.5 GHz BAND.**

#### **A. A 10-Year Term Promotes Investment That Shorter Terms Do Not.**

Many commenters, along with CTIA, support the Commission’s proposal to extend the PAL term from three years to ten years.<sup>18</sup>

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<sup>15</sup> *Id.* at 4.

<sup>16</sup> *Id.* at 5.

<sup>17</sup> T-Mobile Comments at 5.

<sup>18</sup> *Notice* at 8076 ¶ 13; *see also*, e.g., CTIA Comments at 4; AT&T Comments at 3; Ericsson Comments at 5; Mobile Future Comments at 5; Nokia Comments at 2; National Rural Telecommunications Cooperative and National Rural Electric Cooperative Association (“NRTC and NRECA”) Comments at 3; Peoples Telephone Cooperative, Inc. Comments at 4; Union Pacific Comments at 3; Telecommunications Industry Association (“TIA”) Comments at 2; T-Mobile Comments at 4; United States Cellular Corporation (“U.S. Cellular”) Comments at 9; Verizon Comments at 4.

**1. A 10-Year Renewable Term is Critical to the Success of the CBRS Ecosystem.**

The record shows that a 10-year term better accounts for the realities involved in successful network buildout, which “is a multi-year process” that “includes standardizing a new frequency band, developing and certifying equipment, introducing a new band into end-user devices, and deploying infrastructure.”<sup>19</sup> Likewise, a 10-year term will provide “more licensing certainty for PALs [that] will enhance the long-term investment possibilities.”<sup>20</sup> This opportunity to generate returns on network investments will make licensees “more likely to dedicate the substantial resources needed to design, develop, and deploy 3.5 GHz technologies.”<sup>21</sup>

Additionally, a 10-year term is consistent with the proven approach in other bands for innovative services. For instance, the Commission adopted minimum 10-year terms in the *Spectrum Frontiers* millimeter wave bands and for the repurposed 600 MHz band, citing concerns about the timing of testing, deployment, siting obstacles, and the ability to provide an opportunity for investment.<sup>22</sup> Those concerns are relevant for the 3.5 GHz Band as well. As T-Mobile notes, the standard 10-year license term provided “the certainty needed to invest heavily in the nation’s wireless infrastructure [that] helped create today’s strong wireless

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<sup>19</sup> T-Mobile Comments at 4.

<sup>20</sup> AT&T Comments at 4.

<sup>21</sup> Verizon Comments at 5.

<sup>22</sup> See, e.g., U.S. Cellular Comments at 11; Mobile Future Comments at 6. See also *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, et al, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014, 8078 ¶ 176 (2016) (“[A] 10-year license term will give licensees sufficient certainty to invest in their systems, particularly as the new technology is still nascent and will require time to fully develop.”); *Expanding the Economic and Innovations Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd 6567, 6875 ¶ 759 (2014) (adopting a 12-year initial term and 10-year license renewals).

equipment ecosystem.”<sup>23</sup> The Commission should replicate its proven approach to license terms in the 3.5 GHz Band.

## **2. The Current License Paradigm Disincentives Investment.**

The record confirms that shorter license terms are incompatible with any realistic timeline needed to develop and certify equipment, build out CBRS, and get 3.5 GHz Band devices into the hands of end-users.<sup>24</sup> For this reason, a three-year license term – or some other, shorter license term – depresses the prospects for investment in PALs and the CBRS ecosystem at large. As Professor Connolly observes, investment decisions in infrastructure are tied to expected profits from the investment over the period in which the investment will be put to use, and “[w]ith shorter expected time frames, expected profits decrease.”<sup>25</sup> This lowers license valuation and investment in the use of PALs. Indeed, shorter license terms are among the factors likely to diminish the market value for PALs by as much as 50 to 95 percent relative to the value of similar licensed spectrum.<sup>26</sup>

While traditional spectrum rollouts already take a significant amount of time, small cell deployments in the 3.5 GHz Band will require more time to deploy for coverage and capacity given the propagation characteristics of the band: “new sites with new power and backhaul

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<sup>23</sup> T-Mobile Comments at 5.

<sup>24</sup> See, e.g., CTIA Comments at 4; AT&T Comments at 3; Ericsson Comments at 5; Mobile Future Comments at 5; Nokia Comments at 2; NRTC and NRECA Comments at 3; Peoples Telephone Cooperative, Inc. Comments at 4; Union Pacific Comments at 3; TIA Comments at 2; T-Mobile Comments at 4; U.S. Cellular Comments at 9; Verizon Comments at 4.

<sup>25</sup> Connolly Analysis at 4.

<sup>26</sup> CTIA Comments at 4 (citing Harold Furchtgott-Roth, *The Potential Market Value and Consumer Surplus Value of The Citizens Broadband Radio Service (CBRS) at 3550-3700 in the United States*, at B-1-2 (Nov. 2017), <https://www.cbrsalliance.org/whitepapers>).

services that are not shared with equipment operating in earlier frequency bands.”<sup>27</sup> This alone makes it more likely that successful deployment in the 3.5 GHz Band will exceed the allotted three years.<sup>28</sup> Further, shorter license terms do not account for siting obstacles that often complicate delay and buildout, a point that is true in both urban and rural settings.<sup>29</sup> NTCA – The Rural Broadband Association recognizes the “significant investment and time to obtain siting,” and that three-year license terms are insufficient.<sup>30</sup> And, as AT&T points out, shorter license terms ignore the time required to seed new bands into consumer devices and gain robust utilization.<sup>31</sup>

**B. License Renewal Expectancy Provides Necessary Certainty to Invest in a New Band.**

The record supports adoption of a renewal expectancy over the current re-auction policy for several reasons, including that it reduces the risk of auction winners’ stranded investment and promotes investment generally in the 3.5 GHz Band; increases the opportunity for rural deployment; and avoids a complicated, unnecessary, and untested re-auction structure that would distort the otherwise market-driven secondary market. The vast majority of commenters that have participated in spectrum auctions before thus strongly urge the Commission to reverse the current no renewal expectancy policy.<sup>32</sup>

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<sup>27</sup> Nokia Comments at 3.

<sup>28</sup> *Id.* at 2-3 (“[I]t generally takes several quarters to standardize a new frequency band, another year to develop infrastructure equipment and certify it, and over a year to deploy a network. As such, it is a barrier to investment if a PAL carries with it uncertainty of termination after only 3 years.”).

<sup>29</sup> *See, e.g.*, Mobile Future Comments at 6.

<sup>30</sup> NTCA – The Rural Broadband Association Comments at 9.

<sup>31</sup> AT&T Comments at 4.

<sup>32</sup> *See, e.g.*, AT&T Comments at 3; Comcast Comments at 20; T-Mobile Comments at 3; U.S. Cellular Comments at 9; Verizon Comments at 4.

First, under the current rules, PAL licensees risk having investments quickly stranded, and stakeholders will face significant uncertainty in deciding whether to invest at auction.<sup>33</sup> As People's Telephone Cooperative observes, "a longer, renewable license term will encourage investment in the 3.5 GHz Band and reduce the risk of stranded investment."<sup>34</sup> Stakeholders that bid for spectrum at auction seek the certainties of exclusive use and interference protection, yet a short-term license with no renewal undermines the auction format and network investments. As Professor Connolly observes, "firms will be more hesitant to incur sunk costs which could not be recouped in the event that the license is not won a second time."<sup>35</sup>

Second, renewal expectancy is particularly important for investment in rural areas, where buildout often takes longer. As one commenter notes, "[t]here is no merit to the claim that extending PAL license terms will harm rural deployment."<sup>36</sup> In fact, quite the opposite is true: the National Rural Telecommunications Cooperative and the National Rural Electric Cooperative Association state that a 10-year term coupled with renewability will provide "rural service providers and utilities the long-term certainty required to invest" in CBRS.<sup>37</sup> Indeed, when the Commission chose to fund wireless broadband build-out through the Mobility Fund II, it adopted a ten-year term for support, noting that a ten-year term is appropriate because it "may stimulate greater interest in the competitive bidding process," which will in turn "help ensure that funding

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<sup>33</sup> See, e.g., AT&T Comments at 3; CTIA Comments at 6; T-Mobile Comments at 5; U.S. Cellular Comments at 3; Verizon Comments at 6.

<sup>34</sup> Peoples Telephone Cooperative, Inc. Comments at 4. See also e.g., NRTC and NECA Comments at 4 (concluding that a 10-year renewable license term "will provide certainty and consistency needed to encourage investment").

<sup>35</sup> Connolly Analysis at 19.

<sup>36</sup> Mobile Future Comments at 6.

<sup>37</sup> NRTC and NRECA Comments at 4.

is targeted efficiently to expand broadband-capable infrastructure throughout the country.”<sup>38</sup>

Moreover, as the Commission noted, a ten-year term was appropriate “in light of the significant capital and effort needed to deploy and upgrade broadband networks and is consistent with the timeframe used by rural carriers to plan and schedule network upgrades.”<sup>39</sup>

Third, the Commission should reject untested, administratively complicated mechanisms such as re-auctions for subsequent licenses.<sup>40</sup> As Professor Paul Milgrom conceded, a re-auction approach is intended to mimic the role of the secondary market.<sup>41</sup> The Commission already has CBRS secondary market rules, and as discussed below, it should expand those rules by allowing partitioning and disaggregation.<sup>42</sup> There is therefore no reason to support a government-mandated process that regularly re-opens licensing and creates uncertainty for investors. As one commenter explains, rigid three-year timelines for forced resale would likely distort the value of the spectrum and reduce the liquidity and effectiveness of what could otherwise be a flourishing secondary market.<sup>43</sup> A re-auction approach “leave[s] too much uncertainty as to a licensee’s ability to retain its authorization, depressing investment” in the 3.5 GHz Band.<sup>44</sup>

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<sup>38</sup> *Connect America Fund; Universal Service Reform – Mobility Fund*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd 2152, 2190 ¶¶ 89-90 (2017).

<sup>39</sup> *Id.* at 2191 ¶ 91.

<sup>40</sup> *Notice* at 8078 ¶ 19.

<sup>41</sup> Letter from Paul Milgrom, Auctionomics, to Marlene H. Dortch, FCC, GN Docket No. 12-354, at 6 (filed Aug. 7, 2017).

<sup>42</sup> *Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Order on Reconsideration and Second Report and Order, 31 FCC Rcd 5011, 5069 ¶ 209 (2016) (“3.5 GHz Second Report and Order”). See also generally Section V.

<sup>43</sup> Daniel Vincent Comments at 3.

<sup>44</sup> T-Mobile Comments at 5. See also, e.g., AT&T Comments at 3-4.

Finally, some commenters incorrectly argue that a 10-year term or renewal expectancy will result in spectrum hoarding.<sup>45</sup> But, as AT&T notes, the CBRS three-tier framework “inherently protects against any concerns that spectrum will be underutilized.”<sup>46</sup> In other words, GAA services and the use-or-share policy will avoid spectrum lying fallow if there is market interest in a particular area. Furthermore, the adoption of partitioning and disaggregation, discussed below, will also encourage the broad use of spectrum.<sup>47</sup>

### **C. Traditional Performance Requirements Are Not Necessary Given Opportunistic GAA Use.**

The Commission should refrain from adopting traditional performance requirements in the 3.5 GHz Band given the CBRS use-or-share model that allows GAA users to access all 150 megahertz in the band in areas where there is no PAL issued or in use.<sup>48</sup> Spectrum warehousing concerns that typically inform performance requirements are unfounded here.<sup>49</sup> As commenters note, CBRS spectrum will not lie fallow or exclude productive use if either a PAL or GAA operator wishes to provide services, including in unserved areas.<sup>50</sup> Under this novel framework,

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<sup>45</sup> See, e.g., Rural Wireless Association (“RWA”) Comments at ii.

<sup>46</sup> AT&T Comments at 5.

<sup>47</sup> See *infra*, Section V.

<sup>48</sup> See, e.g., *Amendment of the Commission’s Rules with Regard to Commercial Operations in 3550-3650 MHz Band*, Report and Order and Second Further Notice of Proposed Rulemaking, 30 FCC Rcd 3959, 3984 ¶ 64 (2015) (“*First Report and Order*”) (“GAA users will potentially have access to all 150 megahertz in the band in areas where there are no PALs issued or in use and up to 80 megahertz where all PALs are in use.”).

<sup>49</sup> See, e.g., *First Report and Order* at 3997, 4003-04 ¶¶ 113, 138; Verizon Comments at 7; CTIA Comments at 7.

<sup>50</sup> Ericsson Comments at 6 (noting also that the diverse mix of use cases likely to be used in CBRS may not lend themselves to traditional buildout requirements).

the Commission should refrain from imposing unnecessary performance requirements that fail to account for the unique forces, and new uses, at play in the band.

#### **IV. PEA-BASED GEOGRAPHIC LICENSING WILL IMPROVE INTERFERENCE MANAGEMENT AND ALLOW FOR FLEXIBLE AND TARGETED NETWORKS.**

The record supports eliminating census tract licensing and instead adopting PEAs as the geographic license size for PALs.<sup>51</sup> PEAs will avoid the concerns resulting from having 74,000 license areas, including interference management issues, enable access to licensed spectrum to both large and small operators, and allow for flexible and targeted licensing, especially if coupled with partitioning and disaggregation.

As is well established at this point, the use of 74,000 census tracts for licenses would be unprecedented, complicated to manage, and administratively burdensome.<sup>52</sup> With up to seven PALs per license area, more than 500,000 licenses would be auctioned the first year and somewhere between 1.5 and 2 million licenses would be auctioned within the first decade.<sup>53</sup> Assigning PALs in this manner is unquestionably more costly than standard licensing terms and license sizes.<sup>54</sup>

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<sup>51</sup> See Notice at 8080 ¶ 23; see also, e.g., AT&T Comments at 5; Mobile Future Comments at 7; TIA Comments at 3; T-Mobile Comments at 9; U.S. Cellular Comments at 4; Verizon Comments at 10.

<sup>52</sup> See, e.g., Comments of Verizon, GN Docket No. 12-354, RM-11788, RM-11789, at 6-7 (filed July 24, 2017); Comments of AT&T Services, Inc., GN Docket No. 12-354, RM-11788, RM-11789, at 5-6 (filed July 24, 2017); Comments of T-Mobile USA, Inc., GN Docket No. 12-354, RM-11788, RM-11789, at 5 (filed July 24, 2017); Comments of Ericsson, GN Docket No. 12-354, RM-11788, RM-11789, at 6 (filed July 24, 2017); Comments of U.S. Cellular, GN Docket No. 12-354, RM-11788, RM-11789, at 6 (filed July 24, 2017); 5G Americas Comments, GN Docket No. 12-354, RM-11788, RM-11789, at 11 (filed July 24, 2017); Comments of the TIA, GN Docket No. 12-354, RM-11788, RM-11789, at 2 (filed July 24, 2017); Comments of Qualcomm Incorporated, GN Docket No. 12-354, RM-11788, RM-11789, at 6-7 (filed July 24, 2017).

<sup>53</sup> Connolly Analysis at 9.

<sup>54</sup> *Id.*



Further, census tract licensing will create a vast number of interference borders that complicate the ability of PAL licensees to effectively manage interference issues among networks.<sup>55</sup> The borders are a daunting prospect; AT&T estimates that the total shared borders between census tracts are “nearly eight times longer than the total shared borders between PEAs.”<sup>56</sup> As Verizon observes, the resulting “cluttered and chaotic environment could create substantial interference risks” that “significantly limit the utility of the [3.5 GHz Band.]”<sup>57</sup> And, as CBRS equipment will likely use the Time Division Duplex (TDD”) air interface, census tract licensing will increase the potential for co-channel interference where adjacent-area operations are unsynchronized.<sup>58</sup>

Contrary to some claims,<sup>59</sup> census tract licensing is not merely “an inconvenience” to providers seeking to operate wide-area networks in the 3.5 GHz Band, but is a real threat to such networks. For example, if a provider intends to acquire PALs across an entire metropolitan area but is outbid in one census tract, its business plan would be at risk. Professor Connolly sums this point up as follows: “[B]y setting the geographic area of PALs to an area as small as a census tract we know that for many types of technology there will be significant exposure risk.”<sup>60</sup> As

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<sup>55</sup> See, e.g., T-Mobile Comments at 9 (“[Licensees] may be required to introduce guard bands or inefficient scheduling or reduce coverage near border areas[.]”).

<sup>56</sup> AT&T Comments at 5-6.

<sup>57</sup> Verizon Comments at 10.

<sup>58</sup> T-Mobile Comments at 9 (“creat[ing] an increased potential for interference when adjacent-area licensees are operating uplink and downlink at different times”); see also Dynamic Spectrum Alliance Comments at 27 (“The CBRS band plan is based on Time Division Duplexing[.]”).

<sup>59</sup> See NTCA–The Rural Broadband Association Comments at 9.

<sup>60</sup> Connolly Analysis at 6.

one commenter notes, census tracts “introduce[] unnecessary risk and complexity, which will decrease investment and potentially delay deployment of service.”<sup>61</sup>

And yet, while the record demonstrates clear drawbacks to census tract licensing, the purported benefits are unclear. For example, a stakeholder that envisions acquiring PALs to deploy in and around a particular facility may face broader demand for those licenses, especially in urban and suburban settings. The CBRS framework will foster facility use cases like this one by way of GAA spectrum, the use-or-share policy, and the secondary market if partitioning and disaggregation are permitted.<sup>62</sup> Larger license areas thus do not equate with unused or inaccessible spectrum.

Finally, adopting PEAs is a reasonable approach to balance the needs of large and small providers alike. The record reiterates the Commission’s repeated recognition that PEA-sized licenses are conducive to wide-area commercial mobile broadband offerings and they promote opportunity for smaller entities.<sup>63</sup> As Professor Connolly observes, given the known economies of scale in the broadband marketplace, the “optimal market size for a PAL” is likely much closer to the size of a PEA than a census tract.<sup>64</sup> Moreover, both the use-or-share policy and a partitioning and disaggregation policy support adopting an initial license size that better aligns with efficient market allocations. To that end, as Professor Connolly establishes, “the sheer number of secondary market transactions that would be needed to aggregate up from census

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<sup>61</sup> T-Mobile Comments at 9.

<sup>62</sup> *See, e.g.*, Mobile Future Comments at 9. Also, in the case of a “facility use” bidder that wins a PAL but will not operate over its entire area, the same tools – *i.e.*, GAA access and partitioning and disaggregation – provide that areas outside of the facility-based use will not lie fallow if demand exists.

<sup>63</sup> *See, e.g.*, CTIA Comments at 9; U.S. Cellular Comments at 5; T-Mobile Comments at 10-11.

<sup>64</sup> *See* Connolly Analysis at 10.

tracts for several key technologies that require protected service over a larger area dwarfs the number of secondary transactions that would be needed to partition out from PEAs[.]”<sup>65</sup>

In any event, the claim by some commenters that switching to PEAs will prevent small providers from winning licenses at auction does not comport with auction evidence.<sup>66</sup> Small and rural entities frequently win licenses at auction.<sup>67</sup> For example, in the recent 600 MHz incentive auction, in which licenses were auctioned by PEA, 38 of the 50 winning bidders were small or rural businesses.<sup>68</sup> More specifically, more than 60 percent of the 416 PEAs had at least one rural and/or small business winner, and the 27 qualified *rural* bidders won at least one license in more than 70 percent of the PEAs in which they bid.<sup>69</sup>

## **V. COMMENTERS LARGELY SUPPORT PARTITIONING AND DISAGGREGATION TO GENERATE A ROBUST SECONDARY MARKET AND FURTHER SPECTRUM ACCESS.**

Commenters generally support partitioning and disaggregation rules for the 3.5 GHz Band, regardless of the geographic area adopted for PALs.<sup>70</sup> As noted by the City of New York,

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<sup>65</sup> *Id.* at 11.

<sup>66</sup> *See, e.g.*, Wireless Internet Service Providers Association (“WISPA”) Comments at 24-25; Open Technology Institute at New America and Public Knowledge Comments at 19-20; Rural Wireless Association, Inc. Comments at 3-4; Eastern Oregon Net, Inc. Comments at 2.

<sup>67</sup> *See, e.g.*, AT&T Comments at 6; Mobile Future Comments at 9 (noting that “nearly half” of the AWS-3 winning bidders and 55 percent of the 700 MHz winning bidders claimed small business status).

<sup>68</sup> *See Incentive Auction Closing and Channel Reassignment Public Notice the Broadcast Television Incentive Auction Closes; Reverse Auction and Forward Auction Results Announced; Final TV Band Channel Assignments Announced; Post-Auction Deadlines Announced*, Public Notice, 32 FCC Rcd 2786, 2823, Appendix B (2017).

<sup>69</sup> *Closing and Channel Reassignment Public Notice*, Forward Auction Results, <https://auctiondata.fcc.gov/public/projects/1000> (qualified rural bidders won licenses in 73 of the 101 total PEAs in which they bid).

<sup>70</sup> AT&T Comments at 7-8; Blooston Rural Carriers Comments at 7; Cantor Telecom Services, L.P. Comments at 10; City of New York Comments at 4; CTIA Comments at 10; Federated Wireless Comments at 9-10; Mobile Future Comments at 9-10; Motorola Solutions Comments at 7; Nokia Comments at 4-5; NRTC and NECA Comments at 7-8; Rajant at 7; T-Mobile Comments at 12; Union

partitioning and disaggregation will “encourage a thriving secondary market” and help ensure that smaller entities will be able to invest locally.”<sup>71</sup> Most commenters agree that adding this additional flexibility will promote an active secondary market in PAL spectrum.

The Commission should dismiss the arguments opposing partitioning and disaggregation.<sup>72</sup> The Commission has consistently concluded that robust secondary markets will facilitate the efficient use of spectrum, and that same sound public policy belongs here.<sup>73</sup> Partitioning and disaggregation provide opportunities for smaller providers that seek to offer service to smaller, discrete areas.<sup>74</sup> Verizon notes that it engages in “dozens of spectrum transactions every year, often with small and rural entities.”<sup>75</sup> And as CTIA noted previously, the CBRS framework will provide further incentive for PAL licensees to embrace secondary market mechanisms.<sup>76</sup> In particular, a licensee may prefer to enter into a secondary market

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Pacific Comments at 10-11 (supporting the encouragement of secondary market transactions); Utilities Technology Council Comments at 1-2; Verizon Comments at 14-15; Vivint Wireless, Inc. Comments at 5.

<sup>71</sup> City of New York Comments at 4. *See also* Nokia Comments at 4-5; Rajant Comments at 7.

<sup>72</sup> Microsoft Comments at 7; Open Technology Institute at New America and Public Knowledge Comments at 32-33; Starry Comments at 5; WISPA Comments at 43-44.

<sup>73</sup> *See, e.g.*, AT&T Comments at 7-8; *Updating Part 1 Competitive Bidding Rules, et. al*, Report and Order; Order on Reconsideration of the First Report and Order; Third Order on Reconsideration of the Second Report and Order; Third Report and Order, 30 FCC Rcd 7493, 7561 ¶ 158 (citing *Verizon Wireless-Spectrum Co Order*, 27 FCC Rcd 10698, 10715 ¶ 46 (2012)) (“The Commission has ‘encouraged the use of secondary market transactions ... to transition unused spectrum to more efficient use and allow network providers to obtain access to needed spectrum for broadband deployment.’”).

<sup>74</sup> *See, e.g.*, Mobile Future Comments at 9-10; T-Mobile Comments at 12; Verizon Comments at 14 (noting it engages in “dozens of spectrum transactions every year, often with small and rural entities”).

<sup>75</sup> Verizon Comments at 14.

<sup>76</sup> CTIA Comments at 10. While CTIA supports secondary market mechanisms, requiring an “affirmative obligation” for large providers to engage in secondary market transactions with small providers and new entrants not only would distort an actual market-driven secondary market, but such an obligation is unnecessary under the use-or-share that opens unused spectrum for other users. The Commission should

arrangement to derive some benefit from PAL spectrum not in use, rather than allow the spectrum to be used solely by GAA users. With both use-or-share and partitioning and disaggregation in place, the CBRs framework will alleviate concerns that longer license terms and larger license sizes will result in underutilized spectrum.

## **VI. THE RECORD CONFIRMS THAT PUBLICLY DISCLOSING SAS REGISTRATION INFORMATION POSES SERIOUS RISKS AND SHOULD BE ELIMINATED.**

The record broadly confirms the serious risks created by the public disclosure requirements for SAS administrators and that there are no compelling reasons why such risks are necessary.<sup>77</sup> Therefore, to protect competitively sensitive information and decrease security risks, the Commission should eliminate Rule 96.55(a)(3).

As CTIA has noted, the information currently required to be disclosed could provide a bad actor the ability to identify actual users or provide greater precision of site locations to commit malicious acts against communications networks.<sup>78</sup> Other commenters affirm that disclosure of CBSD registration data would “compromise network security and raise serious competitive concerns,”<sup>79</sup> and would reveal “key features of network design [which are] appropriately considered confidential business information.”<sup>80</sup> Others further note that the

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reject any request to impose such an obligation. *See, e.g.*, ATN International, Inc. (“ATN”) Comments at 9.

<sup>77</sup> *See, e.g.*, Alaska Communications Comments at 8; AT&T Comments at 12; Comcast Comments at 31; CommScope Comments at 2; CTIA Comments at 12; Ericsson Comments at 6; NCTA—The Internet and Television Association (“NCTA”) Comments at 16; Nokia Comments at 5; NRTC and NRECA Comments at 8; T-Mobile Comments at 8; Union Pacific Comments at 12; U.S. Cellular Comments at 18; Verizon Comments at 17.

<sup>78</sup> CTIA Comments at 11-12.

<sup>79</sup> Alaska Communications Comments at 8.

<sup>80</sup> Comcast Comments at 31.

current rules are inconsistent with the standards the Commission uses for other critical infrastructure data.<sup>81</sup>

Not only does public disclosure of the information in Rule 96.55(a)(3) create risks, but such public disclosure is wholly unnecessary for the proper functioning of the SAS.<sup>82</sup> As CommScope notes, the Spectrum Sharing Committee of the Wireless Innovation Forum requires SAS administrators to publish certain information that will assist operators in assessing whether there is enough available GAA spectrum.<sup>83</sup> Stakeholders could also contact SAS administrators to request information on a confidential basis to assist in planning GAA deployments. As Comcast observes, SAS Administrators are “well-positioned” to respond to queries from potential users about a proposed deployment “without disclosing the confidential business information of other network operators.”<sup>84</sup> The Commission should therefore adopt its proposal to discontinue the public sharing of CBRS information required by Rule 96.55(a)(3).

## **VII. ADOPTION OF THE QUALCOMM OUT-OF-BAND EMISSIONS PROPOSAL WILL FOSTER 5G AND OTHER INNOVATIVE SERVICES IN THE 3.5 GHz BAND.**

The Commission should revise the emission limits and adopt the Qualcomm proposal described in the *Notice*,<sup>85</sup> as the Qualcomm approach will best promote development of 5G technologies in the 3.5 GHz Band.<sup>86</sup> In 2015, CTIA explained that the power backoff

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<sup>81</sup> See, e.g., AT&T Comments at 12; NRTC and NRECA Comments at 8.

<sup>82</sup> See, e.g., CommScope Comments at 2; Ericsson Comments at 6-7; T-Mobile Comments at 13; U.S. Cellular Comments at 19.

<sup>83</sup> CommScope Comments at 2-3.

<sup>84</sup> Comcast Comments at 3231.

<sup>85</sup> *Notice* at 8090-91 ¶¶ 54-55.

<sup>86</sup> See, e.g., Qualcomm Comments at 1-4; TIA Comments at 4; T-Mobile Comments at 18-19; Verizon Comments at 17.

(Additional-Maximum Power Reduction or A-MPR) required for 20 megahertz and wider channels to comply with the emissions limits in the existing rules “would cause coverage challenges and significantly diminish the utility of the [3.5 GHz Band].”<sup>87</sup> Those concerns persist today. As Qualcomm observes, the current limits “undermine an operator’s ability to offer wider bandwidths and thus limit widescale deployment.”<sup>88</sup> Many commenters agree that “wider bandwidths will be critical for 5G operations,”<sup>89</sup> and that the “unduly restrictive [OOBE limits] will impair both PAL and GAA operations.”<sup>90</sup> Qualcomm’s proposal “offers the best means of improving the mask to allow wider bandwidth operations.”<sup>91</sup>

Notably, because of the emissions mask level at 3720 MHz in the current rules *and* maintained in the Qualcomm proposal, 3.5 GHz operations at the upper edge of the band are required to lower transmit power level by the same amount regardless of the mask used, as shown by Qualcomm.<sup>92</sup> Thus, as Nokia observes, Qualcomm’s proposal “would not have any negative impact to incumbents,”<sup>93</sup> contrary to others’ claims.<sup>94</sup>

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<sup>87</sup> See Comments of CTIA, GN Docket No. 12-354, at 5-7 (filed July 23, 2015).

<sup>88</sup> Qualcomm Comments at 7.

<sup>89</sup> T-Mobile Comments at 18. *See also, e.g.*, ATN Comments at 9-10; Ericsson Comments at 8; Nokia Comments at 6; Verizon Comments at 17; WISPA Comments at 55-57.

<sup>90</sup> Verizon Comments at 17.

<sup>91</sup> Qualcomm Comments at 4-57.

<sup>92</sup> See Qualcomm Comments at 6 (showing in Table 1B that the power backoff required is the same under the existing mask, the Qualcomm mask, and the graduated mask).

<sup>93</sup> Nokia Comments at 2.

<sup>94</sup> See, e.g., Content Companies at 7 and National Association of Broadcasters Comments at 1 (expressing concern about additional emissions into the 3700-3720 MHz portion of the C-band).

The Commission should therefore adopt the Qualcomm proposal, as it will allow operators to make use of wider channels, best promote innovation, and enable efficient frequency and power assignments, while fully protecting incumbents in adjacent bands.<sup>95</sup>

#### **VIII. THE RECORD SUPPORTS NARROW MODIFICATIONS TO THE COMPETITIVE BIDDING RULES GOVERNING PAL ASSIGNMENTS.**

A broad set of commenters support modifications to the competitive bidding rules.<sup>96</sup> As such, the Commission should eliminate the rule that makes one fewer PAL available than sought by potential bidders in a geographic area.<sup>97</sup> As one commenter notes, the Commission should not be in the business of creating “‘artificial scarcity’ by pegging available PALs to the number of PAL applicants.”<sup>98</sup> Further, this rule is particularly problematic because, under the existing rules, the supply of PEAs could decline in subsequent re-auctions. And while that scenario would be mooted by the adoption of a renewal expectancy, as described above, the Commission should jettison it notwithstanding.

Likewise, the Commission should eliminate the rule that prevents any PAL assignments in a market if only one applicant qualifies to bid.<sup>99</sup> Commenters generally agree that no applicant willing to pay for interference protection should be disqualified simply because others

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<sup>95</sup> Notice at 8090 ¶ 54.

<sup>96</sup> See, e.g., Alaska Communications Comments at 9; Cantor Telecom Services, L.P. Comments at 11; CTIA Comments at 14-15; Ericsson Comments at 7; Microsoft Comments at 8; Nokia Comments at 6; Southern Linc Comments at 17; T-Mobile Comments at 14-15; U.S. Cellular Comments at 12-13; WISPA Comments at 50.

<sup>97</sup> 47 C.F.R. § 96.29(c).

<sup>98</sup> NCTA Comments at 15. See also e.g., WISPA Comments at 50-51; Comcast Comments at 22.

<sup>99</sup> 47 C.F.R. § 96.29(d).



in that geographic area are not.<sup>100</sup> The availability of PALs should instead be driven by the needs of network operators and their customers, not by the number of bidders. As CTIA has noted, if mutually exclusive PAL applications do not exist, the Commission has the authority to assign PALs on a non-auctioned basis and it should do so.<sup>101</sup>

The Commission should, however, refrain from adopting Alaska Communications' proposal to give a preference to applicants that express their intent to deploy their channels for broadband capabilities supported by the Connect American Fund.<sup>102</sup> This proposal would tilt the marketplace in favor of a particular business plan and would provide a separate, further subsidy to entities that are already receiving significant public support for deployment.

**IX. CLAIMS THAT THE INITIAL REGULATORY FLEXIBILITY ACT IS FATAL TO THE REGULATORY FLEXIBILITY ACT ANALYSIS PROCESS ARE WRONG.**

The Wireless Internet Service Providers Association ("WISPA") and the Rural Wireless Association ("RWA") mischaracterize the Regulatory Flexibility Act ("RFA") process in asserting that the Initial Regulatory Flexibility Analysis ("IRFA") is so flawed that it "cannot be cured with a final regulatory flexibility analysis ("FRFA")."<sup>103</sup>

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<sup>100</sup> See, e.g., Nokia Comments at 6 ("It would not serve the public interest to deny the benefits of a PAL to a qualified applicant – whether a carrier, industrial complex, hospital, etc. – simply because there was not enough demand by others to compete for PAL rights."); U.S. Cellular Comments at 17 (noting the current rules "would, on occasion, have the effect of withholding a PAL from an otherwise qualified applicant for reasons beyond the applicant's control").

<sup>101</sup> CTIA Comments at 13; see Notice at 8088 ¶ 45.

<sup>102</sup> Alaska Communications Comments at 15-16.

<sup>103</sup> See WISPA Initial Regulatory Flexibility Analysis Comments at 4. See also RWA Comments at 10-11.

The Small Business Administration (“SBA”) has made clear that “[t]he RFA mandates that agencies revise their [IRFA] based on the public comments received.”<sup>104</sup> Such revisions may be of the types that WISPA and RWA are raising — *i.e.*, the identification of small entities, minimizing the economic impact on small entities, and evaluation of alternatives.<sup>105</sup> CTIA expects that, consistent with guidance from the SBA, the Commission’s FRFA will describe the comments received on the IRFA, assess and respond to these issues, and describe any changes made to the proposal in response to the comments.<sup>106</sup>

In short, the IRFA is an initial step in the RFA process and concerns raised in response are not fatal to the process. The Commission has the opportunity and obligation to evaluate and respond to these comments just as the agency is required by the Administrative Procedure Act to respond to non-IRFA comments.<sup>107</sup>

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<sup>104</sup> See SBA, Office of Advocacy, *A Guide for Government Agencies: How to Comply with the Regulatory Flexibility Act*, at 44 (Aug. 2017) (“RFA Guide”); SBA, Office of Advocacy, *The RFA in a Nutshell* A Condensed Guide to the Regulatory Flexibility Act, at 13 (Oct. 2010) (“RFA Nutshell”).

<sup>105</sup> See RFA Guide at 46-48; RFA Nutshell at 13-14.

<sup>106</sup> See RFA Guide at 45; RFA Nutshell at 13.

<sup>107</sup> *Id.*

## **X. CONCLUSION.**

The record in this proceeding supports modifications to the current rules in order to promote long-term investment in the CBRS ecosystem. Therefore, the Commission should promptly (1) extend the PAL term to a traditional 10-year term with an expectation of renewal; (2) license PALs on a PEA basis; (3) permit partitioning and disaggregation of PALs; (4) eliminate the requirement for public disclosure of CBSD registration information; (5) revise the OOB limits consistent with the Qualcomm proposal; and (6) adopt the targeted proposals to modify the bidding procedures. These changes will significantly increase the value of PALs without slowing access to, or diminishing investments already made in, the 3.5 GHz Band.

Respectfully submitted,

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Dated: January 29, 2018

# ATTACHMENT A

**Impact of Proposed Changes to Improve Investment in the 3550-3700 MHz Band**  
**MICHELLE CONNOLLY, PH.D.**

**January 29, 2018**

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## I. QUALIFICATIONS

1. I am a Professor of the Practice in the Economics Department at Duke University. I received a Ph.D. in economics from Yale University in 1996. After working at the Federal Reserve Bank of New York, I became an Assistant Professor of Economics at Duke University in the fall of 1997. I was promoted to Associate Professor of the Practice in 2006. While on leave from Duke University, I served as the Chief Economist of the Federal Communications Commission (FCC) from 2006 to 2007. I reported directly to the Chairman of the FCC and advised the Chairman and his staff on a variety of topics. I returned to Duke University in 2007. In 2008, I was again asked to serve as Chief Economist of the FCC. After my second term at the FCC, I returned to Duke University. In 2012, I was made full Professor of the Practice at Duke.

2. I have taught courses on the Economics of Telecommunications Policy, Intermediate Macroeconomics, Graduate International Trade, and Graduate Advanced Macroeconomics, all at Duke University. I also have taught courses on research methods for undergraduate honors students. I have done research on topics involving theoretical and applied industrial economics. Much of my research considers industries in which there is monopolistic competition. I currently have several working papers analyzing the impact of auction rules on the economic valuation of spectrum used for cellular services. I have published articles in peer-reviewed journals including the *American Economic Review*, the *American Economic Journal: Macroeconomics*, the *Review of Industrial Organization*, the *Review of Network Economics*, the *Journal of Economic Growth*, the *Journal of Economic History* and the *Journal of Development Economics*. I have been awarded a grant from The National Science Foundation, invited to speak at the White House, and testified before Congress. I also have been an invited presenter or panelist on a variety of issues related to telecommunications policy.

3. My curriculum vitae is included as Appendix A.

## **II. TASK**

I have been commissioned by CTIA to provide an analysis of the economic impact of particular changes proposed in the FCC's 2017 *Notice of Proposed Rulemaking (NPRM)* to the Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz Band. Specifically, I have been asked to consider the economic impact of the 2017 *NPRM* proposals to increase the Priority Access License (PAL) license term from three to ten years with the possibility of renewal, to allow partitioning and disaggregation of PALs in secondary market transactions, and to assign a PAL in license areas with a single applicant. I have also been asked to comment on the impact on investment and auction complexity of increasing the geographic size of PALs from census tracts to Partial Economic Areas (PEAs).

## **III. EFFICIENT STRUCTURING OF PALS**

In all industries, uncertainty reduces investment. In the provision of services that rely on spectrum, there are significant sunk costs (which cannot be recovered) and fixed costs (which are independent of volume) beyond sunk costs. When a firm is considering the value of a particular license for usage of given spectrum in a particular market, many factors impact that valuation. Any factors that affect the expected net present value of profits to a firm from the use of this license impact that firm's valuation of the license. Among the factors that the *NPRM* is considering that affect license valuation include expected license duration (which depends on both the license term and the expectation of renewal) and the size of the geographic areas covered by licenses.



The usefulness of an efficient auction is that it allocates a particular license to the firm who can make the most economically efficient use of that license.<sup>1</sup> The rules applied to a license impact not only the absolute economic value of that license, but also potentially impact which firm will have the highest economic use for that license. At the extreme, sufficiently limiting rules can, and have in the past, led to licenses being offered at auction, only to remain unsold. It is important that the license and auction rules are made such that the greatest flexibility of use is feasible. In that way, the auction mechanism will allow the market to determine amongst competing uses/bidders who would be best positioned to make the most economically efficient use of the market.

Given technological advances, particularly with the development and deployment of 5G, the 3.5 GHz band is quickly increasing in potential economic value. The economic importance of the optimal allocation of this spectrum being offered for private use in the new PALs is great.<sup>2</sup> It is crucial that the rules applied to the PALs are designed with the aim of allowing for the most efficient use of this limited resource.

The economics of the provision of services using spectrum underscore that the overall value of PALs both to the market and in terms of consumer surplus will be greater with license terms of ten years rather than three, with a presumption of license renewal, with geographic areas

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<sup>1</sup> R.H. Coase, "The Federal Communications Commission," *Journal of Law and Economics*, Vol. 2 (Oct. 1959), 1-40.

<sup>2</sup> Dr. Harold Furchtgott-Roth (2017) estimates that under the 2015 rules for PALs, the CBRS could have a market value ranging from \$7.5 to \$15.6 billion and a net present consumer surplus from \$80 to \$260 billion. This valuation is based on a presumed discount rate of between 50% to 95% relative to licensed 2.5-2.6 GHz spectrum. Furchtgott-Roth explains that his presumed discount rate would be smaller (i.e. the spectrum value would be greater) if, among other things, PALs were offered in larger geographic areas, had a longer duration of licenses, had a presumption of renewability and had lower administrative costs associated with the large number of frequent auctions. See Harold Furchtgott-Roth, "The Potential Market Value and Consumer Surplus Value of The Citizens Broadband Radio Service (CBRS) at 3550-3700 MHz in the United States," CBRS Alliance White Paper (Nov. 2017), Appendix B, at B-1 and B-2.

defined by PEAs rather than census tracts, with the allowing of partitioning and disaggregation for the purposes of secondary market transactions and with the assignment of PALs even in license areas with only single applicants.

a. Expected Duration of License Term

As previously mentioned, when considering both investing in infrastructure, physical equipment, etc. a firm must consider the present value of the expected increase in profits from this investment. These expected profits are a function of revenues and costs over the entire period during which the firm believes that this investment will be used. With shorter expected time frames, expected profits decrease. Within the CBRS, the expected time frame for a potential bidder for a PAL depends both on the license term and the probability that the license will be renewed. The longer the license term, the longer the period of time when the firm knows that it has the opportunity to use that spectrum with certainty. With the presumption of renewal, the expected period of license duration increases further.<sup>3</sup>

Three-year license terms (even with the option to petition for two consecutive three-year terms in the *first* application window) provide little time for returns to investment given the infrastructure heavy nature of this industry. Combined with the 2015 presumption of no renewal, license valuation, investment, and the subsequent value to consumers would be severely diminished relative to a more standard ten-year FCC license terms with a presumption of renewal.

b. Geographic Area

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<sup>3</sup> The use of an auction mechanism for license renewal will increase uncertainty over the expected duration of an initial license. All else equal, this lowers license valuation and initial investment in the use of the licensed spectrum.

The geographic area covered by a license is similarly important to its economic value to the market and to consumers. As background, past FCC licenses have been auctioned according to different geographic areas. Among these are Basic Trading Areas (BTAs), Major Trading Areas (MTAs), Partial Economic Areas (PEAs), Component Economic Areas (CEAs), Cellular Market Areas (CMAs), and Economic Areas (BEA).

In the presence of fixed costs, there are economies of scale up to a certain volume. It is highly likely that the population level of a census tract is not sufficiently large to take advantage of possible economies of scale for many of the potential uses of the 3.5 GHz band. This is particularly true for the potential deployment of 5G.

Evidence of geographic complementarities between adjacent licenses at the level of Basic Trading Areas (BTAs) and Major Trading Areas (MTAs) demonstrates the importance of geographic coverage to license valuation.<sup>4</sup> For comparison, there are a little under 500 BTAs and there are 51 MTAs in the United States. Hence, even at the level of quite large geographic license areas such as MTAs, evidence of local geographic synergies has been shown to exist.

For technologies/firms who need to guarantee full coverage of an area larger than census tracts, there is an exposure risk of not winning the entire set of PALs needed to cover their desired area and paying more than their valuation for the subset of licenses that they win. As an example, suppose a bidder values geographically adjacent licenses A and B at \$50 and \$75 respectively, but values having both licenses together at \$150.<sup>5</sup> If the bidder bids \$60 for license A and \$85 for

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<sup>4</sup> See Lawrence Ausubel, Peter Cramton, R. Preston McAfee and John McMillan, "Synergies in Wireless Telephony: Evidence from the MTA Auction," *Journal of Economics and Management Strategy*, 6:3, 497-527, 1997, and Patrick Moreton and Pablo Spiller, "What's in the Air: Interlicense Synergies in the Federal Communications Commission's Broadband Personal Communication Service Spectrum Auctions," *The Journal of Law & Economics*, Vol. 41, No. S2 (Oct. 1998), 677-716.

<sup>5</sup> The bidder may value the two licenses together more than individually for various reasons including decreasing interference risk, economies of scale, or need to provide continuity of service among other things.

license B and wins both, he will have a net gain of \$5. If, however, the bidder wins only one of the two licenses, he will have a net loss of \$10. In other words, by setting the geographic area of PALs to an area as small as a census tract we know that for many types of technology there will be significant exposure risk. Additionally, if the PALs were licensed at the census tract, the sheer volume of auctions would make more complex auction designs, such as package bidding to reduce the large exposure risk with such small licensing areas more challenging. In such a setting, bidders requiring larger optimal areas of continuous coverage would lower their bidding and the risk of the spectrum going to a potentially socially less efficient use increases.

Moreover, to the extent that bidders with larger area needs are unable to win all of the necessary groupings of licenses, having to transact with a larger number of license holders for multiple smaller licenses on a secondary market greatly increases the total number of transactions that would be required to move from the initial auction allocation outcome to the economically efficient market allocation. In the absence of transaction costs or other strategic risks involved in such transactions, it would be possible to quickly use a secondary market to achieve the efficient market outcome. Milgrom, Weyl and Zhang (2017) explain:

*In a hypothetical, 'perfect' market, bargaining among parties would lead licenses to migrate to their economically most efficient uses at every point in time, regardless of how they were initially designed. The work of Ronald Coase is often misinterpreted as suggesting something similar might happen in actual practice. Yet Coase rejected this interpretation of his own work. Economic theory, empirical analysis and common sense all clearly suggest this conclusion is false: the rules governing transfers of rights can affect economic efficiency.*

*There are several potentially important problems with traditional systems of spectrum licensing. One is that some licensees might hoard spectrum that they do not plan to use. They could do this either to block entry by competitors or to "tax" or pre-empt future innovators who may need spectrum access. A second problem, familiar from land reallocation, is that one or a small number of holdouts may try to extort high payments for cooperating in large-scale reassignment. These problems were illustrated dramatically by the time, effort and cost required to reallocate spectrum used for over-the-air television broadcast to more valuable uses. Some such spectrum was recently reallocated by the FCC's incentive auction, and the success of that effort teaches another important lesson: market performance can depend deeply on license design. In legislation enacted in 2012, the government decided that TV broadcasters that chose not to sell their broadcast rights could*

*nevertheless be required to shift to a different broadcast channel, greatly reducing the holdout problem.*<sup>6</sup>

It is therefore of large economic and social value that the 3.5 GHz PALs be defined based on geographic areas most likely to be similar to the economically efficient market size. This optimal market size differs from the private perspective of different potential bidders based on the technology that they plan to use and the service that they hope to provide. However, given the incredibly large potential economic value of the CBRS band, it is crucial to define the geographic areas covered by licenses in a manner that will not dissuade what are likely to be tremendously valuable deployments of new technology. I am convinced that setting the geographic areas at the census tract level would dissuade such investments and thus undermine the potential economic value of the CRBS band.

c. PALs in Areas with Single Applicant

Within a license area, if there is only a single applicant interested in having prioritized access to the CBRS band, the FCC should assign that applicant a license. This is because of potential investment effects both within that license area and in geographically adjacent license areas. Within a license area, that single applicant may have a business model that requires protection from GAA users. Without a PAL that applicant may no longer find investment in that license area worthwhile. All else equal, this would diminish potential investment in that license area. Similarly, if there are geographic complementarities across adjacent PALs for an applicant, then the inability to secure a PAL in one license area, diminishes the value of adjacent PALs to

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<sup>6</sup> See Paul Milgrom, E. Glen Weyl and Anthony Lee Zhang, “Redesigning Spectrum Licenses to Encourage Innovation and Investment,” forthcoming, p. 2.

that applicant. In other words, systematically not allowing a PAL to be offered in a license area with only one applicant heightens the exposure risk taken by bidders who need to guarantee service and coverage over a particular area. We generally consider exposure risk as occurring because of the *possibility* of losing the bidding for a single license area amongst a group of licenses that have complementarities for the bidder. Under traditional settings, the existence of a secondary market could help mitigate the exposure risk of losing the bid for a single license. If, however, no other entity is interested in the PAL for a particular area, then the 2015 rule to only offer shared GAA access to that spectrum would *guarantee* that the bidder would *not* be able to create their needed footprint of protected service, even in the presence of a functioning secondary market. This would occur despite the fact that no other bidder finds the license sufficiently valuable to justify applying for it. Imposing interference or congestion risks on an applicant simply because no other entity is interested in a given PAL can in the near term only result in lower overall investment in that license area. Significantly, and as noted in the FCC *Order on Reconsideration*, the areas where there may be only one applicant for a PAL are also likely to be areas in greatest need of deployment.<sup>7</sup> Finally, if the geographic license areas of PALs are increased to PEAs with ten-year renewable terms, there will likely be more bidders participating in the initial auction, implying a lower likelihood that a license area will have only one PAL applicant.

#### **IV. SECONDARY MARKET**

Let us first consider the case where there are no secondary markets of any kind for PALs. Let us further ignore potential costs borne by the FCC in an auction, so as to focus on the transition costs borne by potential bidders. These costs include the cost to each potential bidder of estimating

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<sup>7</sup> Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, *Order on Reconsideration and Second Report and Order*, 31 FCC Rcd 5011, 5023, para. 50.

their valuation of each license and then participating in the individual auction for the licenses that they are interested in acquiring. For any given potential bidder, the total cost of auction-related transactions is strictly non-decreasing in the number of transactions/licenses in the auction. More intuitively, for a given desired coverage area, auction-related costs increase with the number of licenses of interest to a potential bidder. Hence, for a given set of coverage preferences by potential bidders, total/aggregate transaction costs incurred by potential bidders increase with the number of licenses.<sup>8</sup>

There are approximately 74,000 census tracts in the United States. Each CBRs license area will have up to seven PALs. This implies that up to 518,000 licenses would be auctioned in the first year if PALs are defined at the census tract level. Even if in the first application window all applicants use the option to apply for two consecutive three-year terms for a given PAL, there would be up to another 518,000 licenses to auction six years later and again nine years later. Such license rules would lead to somewhere between 1.5 and 2 million license auctions in less than a decade. In contrast, ten-year renewable license terms defined by 416 PEAs would imply only 2,912 license auctions within that same decade. Purely from the perspective of transactions costs borne by bidders to determine their valuation and activity for each license in the auction, the total cost of allocating PALs at the census tract level for three-year non-renewable terms dwarfs that of allocation with ten-year, renewable licenses at the PEA level.

Let us now consider the case where secondary markets for PALs after initial auction allocations are allowed. The question of whether it would be costlier (in terms of secondary market transactions costs – ignoring initial allocation costs) to aggregate up from census tracts or to

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<sup>8</sup> Even if total transaction costs increase less than proportionally with the number of transactions, they are still a positive function of the total number of transactions.

disaggregate down from PEAs depends on the economically optimal market size for a single PAL. At one extreme, if the economically optimal market size were always at the census tract level, then licenses at the census tract level would already replicate the optimal market outcome and there would be no need for secondary transactions. Secondary market transactions costs would be zero. At the other extreme, if the economically optimal market size were always at the level of the PEA, then there would be no secondary market transactions costs if the licenses were originally offered at the level of the PEA.

If one assumes that there is a given cost for each transaction (regardless of the current PAL holder), then which of these secondary markets would have the largest cost would simply reflect whether the optimal market size is closer to that of census tracts or PEAs. Given known economies of scale in this industry, as well as evidence of additional geographic complementarities across licenses as large as BTAs and MTAs, we have clear knowledge that the optimal market size for a PAL is likely to be significantly closer to that of PEAs, than that of census tracts.<sup>9</sup>

Even if one were to assume that the given cost for each transaction would be higher in one case over another (depending on the current PAL holder), the sheer difference in the number of secondary market transactions needed to replicate optimal market outcomes would be extremely likely to dominate in the consideration of total secondary market costs that would be borne by the economy.

Some comments have suggested that the transactions costs of partitioning would be artificially (or even prohibitively) inflated by anti-competitive behaviors of PEA-level PALs. Similar arguments can also be made in terms of the hold out risk if a holder of a single census tract

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<sup>9</sup> Census tracts generally have a population size of between 1,200 and 8,000. They are defined so as to target an optimum population size of 4,000.



PAL knows that a larger entity's network value depends on protected access to spectrum within that one census tract. In either direction, these transactions costs can be large. However, key aspects of the CBRS band help mitigate some of the factors that could lead to extreme secondary transaction costs at the level of a single transaction. Firstly, the fact that each license area could have up to seven PALs diminishes the likelihood – even in the absence spectrum aggregation limits – that a single entity would hold all available PALs. In both directions, this fact would help reduce the likely transactions costs, given the option of negotiating a secondary transaction with multiple PAL holders. Current CBRS spectrum aggregation limits of 40 MHz within a license area further diminish the risk of extreme transactions costs at the level of a single transaction. These aspects decrease the likelihood of excessive or even prohibitive transaction costs for a *single* transaction whether it be for the partitioning of a *single* license area or the addition of that *single* license area to a larger service footprint. Again then, this highlights that in terms of potential transactions costs (or even risks of the market not being able to successfully fully reallocate spectrum use efficiently) the most important factor will be the *number* of transactions that would be needed to efficiently reallocate spectrum use. As explained earlier, the sheer number of secondary market transactions that would be needed to aggregate up from census tracts for several key technologies that require protected service over a larger area dwarfs the number of secondary transactions that would be needed to partition out from PEAs given that not all PEAs would need partitioning and that relatively fewer partitions appear to be desired by firms using more localized technologies.

Finally, there is a key asymmetry in terms of the risk of secondary market transactions costs being excessive. Namely, the use-or-share rule greatly diminishes the concerns of potential hoarding or incomplete deployment over a license area. The use-or share rule implies that firms whose optimal market area is smaller than a PEA have significantly lower expected costs of

gaining access to the CBRS band in their smaller area. This is especially true in the case of commenters who explain that they are in rural areas where they do not expect larger cellular firms to be interested in deployment, but themselves would not be interested in bidding on areas as large as a PEA. In such a case, if a PAL were won by a firm with greater interest in the license's urban areas and the license holder ended up not deploying in the rural areas, then the more localized firm could immediately use the GAA tier in that PAL spectrum. Even beyond that, the non-license holder's ability to make immediate use of the CBRS band through the GAA tier significantly reduces any strategic incentive of a PAL licensee to refuse a secondary market transaction. This is an additional factor decreasing the risk of blocking secondary market transactions to partition beyond the impact of the potential of up to seven PALs in each license area and the 40 MHz aggregation limit.

For these numerous reasons, choosing a geographic area most closely resembling the efficient market size is crucial for allowing initial auction allocations to most closely resemble efficient market allocations and reduce the need for secondary transactions. Given that an auction can never perfectly define the optimal geographic market, secondary transactions remain important and should be facilitated by the FCC. The combined presence of the GAA tier and the potential for up to seven PALs per license area greatly diminishes the risk that a secondary market for partitioning of PEAs would face prohibitive costs.

## **V. MILGROM LETTER AND AUCTION DESIGN**

In his letter filed on behalf of WiFiForward and the Wireless Internet Service Providers Association (WISPA), Professor Paul Milgrom 1) considers the feasibility of auctioning PALs at the census tract level, 2) considers issues of substitutability or complementarity across licenses,

and 3) offers a proposed auction mechanism for license renewal within the setting of three-year PAL licenses. I discuss each in turn. It is important to note that in much of the letter, Milgrom takes *as given* the assignment of PALs at the census tract level with three-year terms.

1. Feasibility of Auctioning PALs at the Census Tract Level Every Three Years

Milgrom suggests that “... simple auctions for tens of thousands of PAL licenses are feasible and reasonable.”<sup>10</sup> As discussed previously, with approximately 74,000 census tracts and up to seven PALs per tract, this would imply up to 518,000 licenses being auctioned in the first auction and somewhere between 1.5 and 2 million license auctions in less than a decade for just the CBRS band. In contrast, renewable ten-year license terms defined by 416 PEAs would imply only up to 2,912 license auctions within that same decade. Purely from a *transactions cost* perspective, the costs of defining PALs at the census tract for three-year terms dwarfs the costs of defining PALs at the PEA level for ten-year terms. Even if the technology is such that the FCC can “feasibly and reasonably” undertake such an endeavor, there is a large cost to the economy. This cost is from the total transactions costs of offering PALs at the level of the census tract - further amplified by the need for subsequent re-auctions.<sup>11</sup>

For interest in a given geographical area, the cost to a individual firm of determining its private valuation for tens of thousands (or even more over time- with non-renewable three-year census tract licenses) and participating in tens or even hundreds of thousands (over time) of auctions individually is clearly increasing in the number of licenses being considered by a firm. Even ignoring the impact of the uncertainty of being able to renew (under any mechanism) on firm

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<sup>10</sup> Letter from Paul Milgrom to FCC, GN Docket No. 12-354 (filed August 7, 2017), para. 2 at 5.

<sup>11</sup> There is also a potential secondary concern that with each subsequent auction significant resources could be spent trying to further adjust auction or license rules.

valuations of licenses and willingness to invest, the sheer magnitude of the number of license auctions that a firm may need to participate in over time in order to deploy a network could run into the hundreds of thousands, if not millions within as short a time frame as 15 years. Even if individual firms were able to keep the per license cost of participating in an auction reasonably low, the sum of the evaluation and participation costs in all of these license auctions could quickly rise to discouraging levels for potential participants (especially those hoping to develop a larger network) over time.

## 2. Issues of Substitutability or Complementarity Across PAL Licenses

Milgrom states that it would be possible for an auction platform to conduct tens of thousands of “... *simple* [emphasis added] auctions on a single platform in a short period of time.”<sup>12</sup> Milgrom explains that while many simultaneous simple auctions are feasible, their design may not be sufficiently complex as to allow winning bids to accurately reflect the possibility of substitutability or complementarity across PALs.

From the perspective of individual bidders, licenses within an auction may be substitutes. For example, a bidder may wish to achieve a particular market scale, but be less concerned with the exact geographic location of that particular market. In such a case, the bidder might initially target a market like Boston, but if it finds that the bids in that market are getting too high, the bidder could switch to bidding on a market like Washington, D.C. if the current bids for the Washington, D.C. license were lower.<sup>13</sup> I.e. as the price of one license increases, bidders shift their demand to another license that is seen by the bidder as a possible substitute.

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<sup>12</sup> Letter from Paul Milgrom to FCC, GN Docket No. 12-354 (filed August 7, 2017), para. 6 at 2.

<sup>13</sup> While not relevant for the current CBRS band, when different frequencies are offered within the same geographic area, then bidders may similarly see these licenses of different frequencies as substitutes.

Within an auction, licenses may also be complements in the sense that synergies across two licenses can lead bidders to increase the demand for a license that is seen as a complement to another license when the latter's price is lower. The licenses are complements in that their value if won together is greater to a particular bidder than the sum of the value of the two licenses separately. Two separate peer reviewed publications have empirically demonstrated the presence of such local synergies in the first two broadband PCS spectrum auctions for geographically adjacent licenses.<sup>14</sup>

Milgrom suggests that the degree to which PALs may be substitutes or complements is limited by the original focus on very local uses for the band and the presence of the Generalized Authorized Access (GAA) tier.<sup>15</sup>

Milgrom suggests that since the original proposed uses for the 3.5 GHz band were very local uses, "... the substitutes and complements relationships among the licenses are much weaker, greatly reducing any need for the relatively complex auction designs that the FCC has traditionally favored."<sup>16</sup> While very local uses may have been at the forefront in the 2015 *First Report and Order*, this is not a natural limitation to the possible use of the CBRS band. Economically, the CBRS auction design should not *ex-ante* preclude the use of other possible technologies such as 5G. However, the 2015 rules potentially preclude much participation in the PAL auctions by increasing exposure risks, total auction and secondary market transactions costs, and uncertainty

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<sup>14</sup> See Lawrence Ausubel, Peter Cramton, R. Preston McAfee and John McMillan, "Synergies in Wireless Telephony: Evidence from the MTA Auction," *Journal of Economics and Management Strategy*, 6:3, 497-527, 1997, and Patrick Moreton and Pablo Spiller, "What's in the Air: Interlicense Synergies in the Federal Communications Commission's Broadband Personal Communication Service Spectrum Auctions," *The Journal of Law & Economics*, Vol. 41, No. S2 (Oct. 1998), 677-716.

<sup>15</sup> Letter from Paul Milgrom to FCC, GN Docket No. 12-354 (filed August 7, 2017), paras. 9, 14-19 at 3-5.

<sup>16</sup> *Ibid*, para. 14 at 4.

over the expected time frame under which a license holder can receive protected access to spectrum over a larger service area.

The use of the GAA tier might offer some level of substitutability or complementarity with PALs within a local area. However, it is not the case that within a geographic license area, GAA use, which must accept interference from all other users, can be considered a perfect substitute for a PAL, which receives protection from GAA operations. Similarly, the existence of the GAA tier does not imply that PALs are no longer potential substitutes or complements for other PALs.

As in previous spectrum auctions, the possibility of substitutability or complementarity across PALs remains. A “simple” auction design would therefore be less efficient than the FCC’s simultaneous multiple round auction design, which was designed to at least partially accommodate for such substitutability or complementarity across licenses. Less efficient auction designs lead to the misallocation of spectrum rights relative to more efficient designs, where optimal allocation of rights is determined by the economic efficiency with which different bidders can utilize the spectrum. In other words, while a simple auction design might be technically feasible at the census tract level, it is *not an efficient auction design* for the 3.5 GHz band. More efficient auction designs exist and are standard at the FCC, but would be quite difficult to undertake at the census tract level.

Milgrom states “The general lesson is that past spectrum auctions in the US and around the world have been designed to accommodate the problem of bidding for licenses that may be substitutes or complements. The auction features employed – for example, multi-round auctions with bid switching or combinatorial package bidding – mitigated those problems, but at the cost of increased complexity, both of the auction system and of the participants’ bidding problem. In

auctions of large scale, such complexity makes it challenging for bidders to participate and bid effectively.”<sup>17</sup>

3. Proposed Auction Mechanism for License Renewal within the Setting of Three-Year PAL Licenses

Milgrom’s *Letter to the FCC* seeks to address a balancing of the need for sufficiently long expected license durations to encourage investment, with the risk of creating effectively perpetual licenses which can block new uses and discourage further innovation.<sup>18</sup> Based on this real tradeoff, Milgrom proposes that rather than offering three-year licenses with automatic re-auction every three years, the FCC might instead consider the same three-year licenses with a “foothold” auction system intended to resemble an active secondary market.

In terms of the auction design for the initial assignment of PALs, Milgrom proposes a simultaneous ascending clock auction where a bidder indicates the license areas it is willing to license at the opening price. Prices then would rise by a given increment, in each round in license areas with excess demand. After each round, a bidder would either leave its list of demanded licenses unchanged or would reduce its list to only licenses for which the current price does not exceed its willingness to pay for that license.<sup>19</sup>

After the initial auction, Milgrom proposes a “foothold” auction system which

*... offers bidding credits for incumbents, and would work as follows. Licenses with three-year terms would be made available for sale every three years, on a staggered schedule. The general format of the auction would be [the simultaneous ascending clock auction] described above, but for the incumbent licensee, payments would be determined differently. An incumbent that wins back its license in the auction would pay only a fraction  $X$  of the auction-determined license price. If the incumbent loses the auction, it would be compensated with a (preferably, transferable) bidding credit that it could apply to purchase other licenses. The value of the credit would be a fraction  $1-X$  of the auction-determined license price.*<sup>20</sup>

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<sup>17</sup> Ibid, para. 13 at 4.

<sup>18</sup> Ibid, para. 22 at 6.

<sup>19</sup> Ibid, para. 19 at 5.

<sup>20</sup> Ibid, para. 24 at 6.

Milgrom explains that “By design, the economic effect of this auction is to create something resembling an active secondary market for licenses....”<sup>21</sup>

I agree with Milgrom that the optimal allocation of spectrum usage rights needs to consider the tradeoff between establishing sufficiently strong and sufficiently long expected durations to encourage optimal innovation and investment given current conditions without creating de-facto perpetual property rights that make eventual reallocation of spectrum rights to more efficient uses slow and costly, as we saw in the case of the spectrum recently auctioned in the Incentive Auction. I do however see some limitations to Milgrom’s proposal in the specific context of the 3.5 GHz band.

1. While not specifically recommended by Milgrom, within the setting of three-year license terms, forced re-auction every three years (with the exception of the first application which allows for two consecutive three-year terms) seems overly short for the purposes of the types of investments and the length of time needed before being able to offer services using these new investments that potential PAL holders might need to undertake given the type of technology they might be using. It also would likely imply a tremendous amount of resources being spent both by PAL holders and potential new bidders to so frequently have to reconsider the valuation that a PAL might have to them at that particular moment (especially when there is built-in risk of losing the PAL in the next round of auctions only three years later).

2. Milgrom’s staggered schedule for PAL re-auctions would allow for a third of PALs to be made potentially available to new users each year. Although this increases the likely fluidity

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<sup>21</sup> Ibid, para. 25 at 6.



of the market for PALs, the staggered schedule increases exposure risk for potential bidders. In particular, the staggered schedule could be a specific problem for the issue of complementarity across licenses in that in each (now annual) auction, only a third of PALs would be offered for in auction at any one time. It also increases the risk for existing PAL licensees who see their current licenses as complementary (whether within or across license areas) as they would now face a risk of losing a subset of their preferred package of licenses on an *annual* basis.

3. The additional uncertainty over renewal will, relative to a presumption of renewal, reduce both license valuation and overall investment as firms will be more hesitant to incur sunk costs which could not be recouped in the event that the license is not won a second time. The negative impact of this uncertainty on not only valuations, but particularly on investments, will be especially large if applied in the context of a three-year license term.

4. Determination of the appropriate “bid credit” for current PAL holders in renewal auction will be difficult and rife for encouraging rent extraction. In Milgrom’s notation,  $X$  is a value between 0 and 1, and represents the fraction of the winning bid that an incumbent PAL holder would have to pay to retain its PAL *if* it wins the re-auction after its three-year license term.  $(1-X)$  times the final auction winning bid is the amount of compensation the incumbent PAL holder receives if they instead do not re-win their original PAL.

Hence, higher  $X$  will, all else equal, lead to bids on the part of incumbents that are closer to their true valuations, while lower  $X$  will allow incumbents to bid significantly above their true valuations, greatly increasing their likelihood of retaining their current PAL. For example, with

$X=0.5$  (as mentioned by Milgrom as an option in the case of triennial auctions) an incumbent PAL holder could bid up to twice their true valuation for their current PAL.<sup>22</sup>

Even once  $X$  is determined by the FCC, if an incumbent is certain that a competing bidder has a valuation significantly above the incumbent's valuation divided by  $X$ , the incumbent might strategically bid beyond the normally assumed value of its maximum bid (its true valuation divided by  $X$ ). The incumbent can do so if it is confident that it will still be outbid by the competing bidder and so can push the winning bid higher in an attempt to receive greater compensation after. There is of course a maximum point beyond which the incumbent would not find it in its best interest to push. Still, for sufficiently large differences in valuations between a potential bidder and an incumbent, an incumbent could have a range of values greater than its normal maximum bid where it would be willing to bid simply to push up the final winning bid. Such behavior would in many ways not be tremendously different from other types of potential strategic behavior in secondary markets although more consideration would be required to try to estimate the potential magnitudes.

Regardless, with sufficiently low  $X$ , this method would begin to mimic a system with guaranteed perpetual licenses. With sufficiently high  $X$ , this method would begin to mimic a system of three-year license terms with no renewal.

5. The bidding credit given to an incumbent PAL holder if it is not able to re-win its original PAL in the next auction may be difficult to implement. Milgrom appropriately states that it would preferably be transferable. The value of this compensation, equal to  $(1-X)$  of the final winning bid, is not being offered as cash, but rather as a value that the incumbent could either use to potentially bid on other licenses or (if transferable) might be able to sell on a secondary market

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<sup>22</sup> This also implies that a potential bidder would need to have a true valuation of the license slightly more than twice that of the incumbent in order to win the incumbent's PAL.

to other potential bidders. If not transferable, then this FCC “store credit” only has value to the incumbent to the extent that they are interested in bidding on other PALs in a different geographic license area, or if this credit can be used in other FCC auctions in the future. If transferable, this credit is potentially of much greater value to the incumbent to the extent that it is able to sell it on a secondary market. Whether it would be able to get full valuation for the stated credit would depend on the amount of competition between other bidders for purchase of this credit. With sufficient potential buyers of this credit, it should yield a competitive market price.

Although the Milgrom “foothold” auction system is intriguing in its attempt to find a mechanism that can force existing license holders to participate in the secondary market with potentially less risk of holdout or other anti-competitive behaviors. Still, it poses several concerns. First, other strategic behaviors could arise in the foothold system, particularly in the efforts to set the rate,  $X$ , or in terms of an auction type of hold out. Further, the introduction of this rather complex approach within the setting of three-year terms and unknown subsidy rates seems costly in terms of firms’ costs to internalize this new auction approach. The uncertainty of how the subsidy rate will be determined in the future and the additional uncertainty over the expected duration of the license will, all else equal, lower license valuations and initial investments. And, to the extent that the FCC sets standards in the CBRS that not only allow, but encourage, a well-functioning secondary market, the costs of transitioning to this new auction mechanism, especially in the three-year, census tract setting considered by Professor Milgrom in his letter, seem high.

## **VI. PRIOR INVESTMENTS WILL NOT BE STRANDED**

Many comments have been filed stating that changes to the geographic license area of PALs will strand prior investments intended to eventually function using PALs in the CBRS band.

These comments generally refer to investments which were made for *current use* (as with 3.65 GHz Non-Exclusive Nationwide licenses) and with the *intent* to undertake additional costs if successful at winning PALs at auction. Even without any changes to PALs, participation in an auction implies only a probability of winning, not a guarantee. Any business investing does so based on their expectations of returns. Changing the terms of the PALs will very likely affect the expectations that firms may have had about their likelihood of winning a PAL at auction. However, no individual firm was ever 100 percent guaranteed that it would win a PAL. It is likely that some of these previous investments were made based on the knowledge that if the firm were not successful at winning a PAL, that the investments could be used in the GAA tier. The return to those investments might be lower when used in the GAA tier relative to a PAL, but the option of using these investments in the GAA tier remains regardless of the proposed changes to PALs. CBRS rules allow GAA users to operate on any frequencies not in use by PALs: “When Priority Access rights have not been issued (e.g., due to lack of demand) or the spectrum is not actually in use by a Priority Access licensee, the SAS will automatically make that spectrum available for GAA use on a local and granular basis.”<sup>23</sup>

Expenditures related to the development of technical standards, certifications etc. remain relevant even with the proposed changes to PALs within the CBRS system.

## VII. CONCLUSION

The FCC’s 2017 *Notice of Proposed Rulemaking (NPRM)* proposes several key changes to the Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz Band. At their core is an attempt to provide a license and auction design within the three-tiered setting of the 3.5 GHz

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<sup>23</sup> See Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, *Report and Order and Second Further Notice of Proposed Rulemaking*, 30 FCC Rcd 3959, 4081, para. 419.

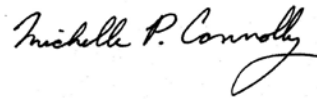
band that will best allow for a range of technologies and services to have the possibility to develop. The original 2015 rules created three-year, non-renewable PALs licensed at the level census tract level that would effectively preclude the possibility of significant participation of firms interested in developing and deploying technologies, such as 5G, requiring protected service over larger areas. The 2017 *NPRM* proposes changes that will unambiguously increase the economic value of and total investment in the CBRS band. The key proposed changes are increasing the expected duration of the PALs by increasing the license term to ten-years – with the possibility of renewal, enlarging the geographic license area to PEAs, allowing for the assignment of a PAL in license areas with only one PAL applicant, and supporting the partitioning or disaggregation of PALs on the secondary market.

These proposed changes all move the auction design for the CBRS to a much more economically efficient auction design which will lead to greater valuations, greater investments, a more fluid secondary market (with likely lower aggregate transactions costs), and ultimately spectrum usage with greater consumer surplus. Even with a fluid secondary market, total secondary market transactions costs increase the more dissimilar a geographic license area is from the economically efficient market area. Hence setting the geographic license areas to PEAs, rather than census tracts will not only reduce auction transactions costs borne by potential bidders, but will also decrease the total number of secondary market transactions necessary for the market to potentially reallocate resources to their most efficient use.

While concerns over possible anti-competitive and/or hold out behaviors on any secondary market are worth considering, these should be greatly diminished by the proposed CBRS rules. The presence of the GAA tier, along with the use-or-share CBRS rules in cases where a PAL is not being used and the offering of up to seven PALs within a license area (with a 40 MHz spectrum

aggregation cap per entity), will not only continue to allow for more granular local use for certain technologies, but also should significantly reduce the risk of anticompetitive behaviors in the secondary market.

In addition to increasing the likelihood that the license area better matches the economically efficient market (thus improving the efficiency of the initial allocation and reducing the costs of the secondary market), moving to larger geographic license areas has two other key benefits. By greatly decreasing the number of license auctions (from potentially 518,000 to 2,912 in just the initial auction), potential bidders will face reduced auction transaction costs and the FCC can use its more standard auction design so as to at least partially accommodate for the issue of licenses being possible substitutes or complements. This again raises the efficiency of the allocation of the spectrum.

A handwritten signature in black ink, reading "Michelle P. Connolly". The signature is fluid and cursive, with a large, stylized 'M' and 'C'.

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Michelle P. Connolly

## APPENDIX A.

CURRICULUM VITAE

December 2017

### **DUKE UNIVERSITY** **Department of Economics**

MICHELLE P. CONNOLLY

213 Social Sciences, Box 90097  
Department of Economics, Duke University  
Durham, NC 27708  
(919) 475-0325  
[mconnoll@duke.edu](mailto:mconnoll@duke.edu)

#### EDUCATION

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Ph. D., Economics, Yale University, 1996  
M. Phil., Economics, Yale University, 1993  
M. A., Economics, Yale University, 1992  
B. A., Economics, Phi Beta Kappa, Summa Cum Laude, Distinction in the Major, Yale University, 1990

#### APPOINTMENTS

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Professor of the Practice, Duke University, August 2012 - present  
Associate Professor of the Practice, Duke University, Sept. 2006 - July 2012  
Chief Economist, Federal Communications Commission, Aug. 2008 – 2009  
Economics Director of Duke in New York: Financial Markets and Institutions Program, Jan. 2007 - June 2009  
Director of EcoTeach, Duke University, Sept. 2007 – July 2008  
Chief Economist, Federal Communications Commission, Aug. 2006 – 2007  
Director of EcoTeach and Assistant Professor of the Practice, Duke University, Sept. 2005 – Dec. 2006  
Assistant Professor, Duke University, Sept. 1997 – Aug. 2005  
Economist, International Research Function, Federal Reserve Bank of New York, Aug. 1996 – 1997

#### FIELDS

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Macroeconomics, Int'l Trade, Development, Growth, Telecommunications, Media

## GRANTS

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National Science Foundation, Secure and Trustworthy Cyberspace Medium Grant, “Dollars for Hertz: Making Trustworthy Spectrum Sharing Technically and Economically Viable,” 2013-2017

Teagle Grant, Duke University, 2008

Spencer Grant, Duke University, 2006

Arts and Sciences Research Council Grant, Duke University, 1998

Arts and Sciences Research Council Grant, Duke University, 1997

John F. Enders Research Grant, 1995

## HONORS AND AWARDS

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*Howard D. Johnson Trinity College Teaching Prize*, 2011

Top 5% of Duke University Undergraduate Instructors: Fall 2009, 2010, and 2011, Spring 2017

Honorary Faculty Speaker, Duke University Economics Majors Graduation, Spring 2010

Raymond Powell Teaching Prize, Yale University, 1994

Yale University Dissertation Fellowship, 1995

Ryoichi Sasakawa Young Leaders Fellowship, 1993

Yale University Fellowship, Full Support, 1990-1994

William Massee Prize for Excellence in Economics, (Best Academic Grade Record in Economics), Yale University, 1990

Phi Beta Kappa, Yale University, 1990

Summa Cum Laude, Yale University, 1990

National Merit Scholar, 1987

## PUBLICATIONS

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Connolly, Michelle, Clement Lee and Renhao Tan, “The Digital Divide and other Economic Considerations for Network Neutrality,” *Review of Industrial Organization*. December 2016: 1-18. DOI 10.1007/s11151-016-9554-8.

Connolly, Michelle and Kei-Mu Yi, “How Much of South Korea's Growth Miracle Can be Explained by Trade Policy,” *American Economic Journal: Macroeconomics*. Vol. 7, Issue 4, October 2015: 188-221.



Dowd, Jason, Michelle Connolly, Robert Thompson and Julie Reynolds, "Improved Reasoning in Undergraduate Writing through Structured Workshops," *The Journal of Economic Education*. Vol. 46, Issue 1, 2015: 14-27.

Connolly, Michelle and James Prieger, "A Basic Analysis of Entry and Exit in the US Broadband Market, 2005-2008," *Review of Network Economics*. Vol. 12, No. 3, September 2013: 229-279.

Connolly, Michelle, "Proposed FCC Incentive Spectrum Auctions: The Importance of Re-optimizing Spectrum Use," Chapter in *Communications Law and Policy in the Digital Age: The Next Five Years*. Ed. Randolph May. 2012.

Connolly, Michelle and James Prieger, "Economics at the Federal Communications Commission, 2008-2009: Broadband and Merger Review," *Review of Industrial Organization*, Nov. 2009, Vol. 35: 387-417.

Sa, Nelson, Michelle Connolly and Pietro Peretto, "Sustaining the Goose that Lays the Golden Egg: A Continuous Treatment of Technological Transfer," *Scottish Journal of Political Economics*, Sept. 2009, Vol. 56: 492-507.

Peretto, Pietro F. and Michelle Connolly, "The Manhattan Metaphor," *Journal of Economic Growth*, Dec. 2007, Vol. 12, 4: 329-350.

Connolly, Michelle and Evan Kwerel, "Economics at the Federal Communications Commission: 2006-2007," *Review of Industrial Organization*, Nov. 2007, Vol. 31: 107-120.

Connolly, Michelle and Diego Valderrama, "Implications of Intellectual Property Rights for Dynamic Gains from Trade," *American Economic Review*, May 2005.

Connolly, Michelle, "Human Capital in the Post-Bellum South: A Separate but Unequal Story," *Journal of Economic History*, June 2004, Vol. 64, 2: 363-399.

Connolly, Michelle, "The Dual Nature of Trade: Measuring its Impact on Imitation and Growth," *Journal of Development Economics*, Oct. 2003, Vol. 72, 1: 31-55.

Connolly, Michelle and Pietro F. Peretto, "Industry and the Family: Two Engines of Growth," *Journal of Economic Growth*, March 2003, Vol. 8, 1: 115-148.

Connolly, Michelle and Jenessa Gunther, "Mercosur: Implications for Growth in Member Countries." *Current Issues in Economics and Finance*, Federal Reserve Bank of New York, May 1999, Vol. 5, no. 7.

## WORKING PAPERS

---

Connolly, Michelle, Nelson Sá, Azeem Zaman, Chris Roark, and Akshaya Trivedi, “The Evolution of U.S. Spectrum Values Over Time,” Economic Research Initiatives at Duke Working Paper No. 247, 2017.

Connolly, Michelle, Renhao Tan, Zachary Lim, and Jackie Xiao, “Structural Estimation of FCC Bidder Valuation,” 2017.

Connolly, Michelle, Alexandra Zrenner, and Chidinma Nnoromele, “The Impact of Small Bidder Preferences in Spectrum Auctions,” 2017.

Sá, Nelson and Michelle Connolly, “An Economic Model of Tiered Spectrum Access,” 2017.

Connolly, Michelle, Repton Salisbury, Akshaya Trivedi and Azeem Zaman, “FCC Spectrum Auction Rules,” 2017.

Connolly, Michelle, Ricardo Martinez-Cid, Wenfei Jiao, “A Brief Review and Analysis of Spectrum Auctions in Canada,” 2017.

Connolly, Michelle and Diego Valderrama, “North-South Technological Diffusion and Dynamic Gains from Trade,” FRB of San Francisco Working Paper No. 2004-4, 2004.

## OTHER WORK

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Op-Ed. Many Reasons to Renew Obama Fast-Track Authority on Trade. *Raleigh News and Observer*, June 10, 2015.

Guest Editor. “The 80th Anniversary of the 1934 Communications Act and the Inception of the Federal Communications Commission,” *Review of Industrial Organization*: Vol. 45, Issue 3, 2014.

“An Analysis of Entry and Exit in the US Broadband Market in Recent Years,” with James Prieger, Report to the Broadband Task Force, FCC, 2011.

Book Review on *The Race between Education and Technology* by Claudia Goldin and Lawrence Katz. *Economic History Review*, Vol. 63.3, Aug 2010.

Book Review on *Intellectual Property and Development*, edited by Carsten Fink and Keith E. Maskus. *Journal of Economic Literature*, June 2006, Vol. XLIV, pp. 475-458.

“The Impact of Removing Licenses and Restrictions to Import Technology on Technological Change.” Background Report for the World Development Report 2000/2001, July 1999.

## TEACHING

---

Economics of Telecommunications Policy, Duke University, 2012

Honors Research Seminar, Duke University, 2007 – 2018

Intermediate Undergraduate Macroeconomics, Duke University, 1998 - 2000, 2002, 2003, 2005, 2006, 2010, 2012, 2014, 2016

Graduate International Trade, Duke University, 2002, 2003, 2005

Advanced Graduate Macroeconomics, Duke University, 1997 – 1999

## UNIVERSITY SERVICE

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Global Education Committee, Arts & Sciences Council, Duke University, August 2017 - present

Faculty Advisor to Duke Consulting Club, Fall 2017 - present

Created and Head the Spectrum Lab in Economics, Duke University, seven undergraduate and two master's lab members currently, January 2016 – present

Duke Conversations Dinner Host, April 4, 2017

Interviewer for Duke Nominations for Rhodes, Marshall, Mitchell, and Schwarzman

Scholarships, Fall 2016 - present

Committee on Diversity in the Economics Major, 2016 - present

Vice-President, Phi Beta Kappa, Duke University Chapter, 2014 – present

Director of Honors Program, Department of Economics, 2007– 2008, 2009 – present

Committee on Members in Course, Phi Beta Kappa, Duke University Chapter, 2009 – present

Duke Alumni Association Board Member, Sept. 2012 – May 2016

Faculty Advisor to Duke Fed Challenge Team, 2015

Duke Library Council, 2012 – 2015

Duke Faculty-Student Connections Work Group, 2012

Duke Arts and Sciences Research Council Grants Award Committee, 2011 – 2013

Director of Duke in NY: Financial Markets and Institutions Program, 2007 – 2009

Co-creator of Duke in NY: Financial Markets and Institutions Program, 2007

Director of EcoTeach, Department of Economics, 2005 – 2008

Duke University Academic Council, 2007 – 2008 and 2009 – 2010

Committee on the Undergraduate Experience, Duke University, Fall 2005

Forum for Excellence in Undergraduate Education, Fall 2005 – Fall 2009

## PRESENTATIONS IN LAST TEN YEARS

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“The Evolution of U.S. Spectrum Values Over Time,” TPRC Capitol Hill Briefing (one of four TPRC conference papers chosen for the Capitol Hill Briefing), Rayburn House Office Building, September 7, 2017.

“The Evolution of U.S. Spectrum Values Over Time,” TPRC, Research Conference on Communications, Information and Internet Policy, Antonin Scalia Law School, George Mason University, Arlington, VA, September 9, 2017.

Panelist for “The Free State Foundation’s Ninth Annual Telecom Policy Conference,” National Press Club, Washington, DC, May 31, 2017

Panelist for “The Future of the Internet in a Post-Internet Regulation World,” Technology Policy Institute, National Union Building, Washington, DC, May 23, 2017

Panelist for “The Impact of Broadband Competition on Consumer Welfare, Innovation, and Productivity in the United States: A Policy Forum,” Georgetown on the Hill, Rayburn House Office Building, Washington, DC, May 9, 2017

Panelist for “The Role of Economic Liberty in the United States,” The Federalist Society, National Press Club, Washington, DC, March 28, 2017

Participant at White House Roundtable Discussion of the Trans Pacific Partnership, Roosevelt Room, Washington, DC, Oct. 25, 2016

Discussant for “The Future of the Internet Ecosystem in a Post-Open Internet Order World” Technology Policy Institute and the University of Pennsylvania Law School’s Center for Technology, Innovation and Competition, National Press Club, Washington, DC, January 8, 2016

Panelist for “Does Platform Competition Render Common Carriage Irrelevant in an IP World?” Progressive Policy Institute, Washington, DC, November 20, 2013

Panelist for “A Workshop on How to Meet the Information Needs of Communities.” UNC Center for Media Law and Policy, Jan. 20, 2012

Chautauqua Lecture for Duke University Freshman, 2011 and 2012

Panelist for Congressional Hispanic Caucus Institute Public Policy Conference, Sept. 2011

Witness for the Congressional Hearing on “Promoting Broadband, Jobs and Economic Growth Through Commercial Spectrum Auctions.” For the Communications and Technology Subcommittee of the House Energy and Commerce Committee. June 1, 2011

Panelist with Paul Milgrom, Michael Riordan, and Hal Varian for the Presentation of the FCC Spectrum Auction Authority Letter to President Obama. White House. April 6, 2011

Panelist at the Broadband Breakfast, “Setting the Table for the National Broadband Plan: Collecting and Using Broadband Data,” Washington, DC, February 2010

AAC&U Annual Meeting, “Systematic Improvement of Teaching and Learning Through Experimentation and Assessment,” Washington, DC January 2010

NBER's Summer Institute 2009, Economic Fluctuations and Growth, Small Working Group, Cambridge, July 2009

Systematic Improvement of Undergraduate Education in Research Universities, Duke University, June 12, 2009

Panelist and Moderator, ACLP Advanced Communications 2009 Summit, Advanced Communications Law and Policy Institute, New York Law School, April 2009

Keynote Panelist, Wireless Technologies: Enabling Innovation and Economic Growth Conference, Georgetown Center for Business and Public Policy, Washington, DC, April 2009

*Martin H. Crego Lecture in Economics*, All College Lecture, “Economics and Public Policy at the FCC,” Vassar College, March 2009

Forum for Excellence in Undergraduate Education, Kennedy School, March 2009, Nov. 2007, Nov. 2006, and Nov. 2005

“Universal Service Fund Reform,” Phoenix Center 2008 Annual U.S. Telecoms Symposium: Telecoms Priorities for the New Administration, Washington, DC, Nov. 2008

“Intellectual Property Rights and International Trade,” Conference on Regional Determinants of Productivity Growth, University of Washington, Oct. 2007

“Economic Drivers in Policy Formulation,” Spectrum Management Conference, Law Seminars International, Washington, DC, Sept. 2007

Keynote Speaker, “Antitrust Developments in the United States,” CRA Int’l Antitrust Conference, Brussels, June 2007

Keynote Speaker, “Economic Analysis in FCC Decision Making,” FCBA and Stanford Institute on Economic Policy Research, April 2007

## PROFESSIONAL ACTIVITIES

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Columbia University Institute of Tele-Information (CITI) Fellow, September 2017 - present  
Yale Alumni School Committee Volunteer, October 2012 – present  
Board of Academic Advisors, Free State Foundation, July 2011 – present  
Steering Committee Member for NSF funded “Enhancing Access to the Radio Spectrum (EARS) Initiative, Spring 2010  
Consultant to the National Broadband Task Force, 2009 – 2010  
2009 TPRC Program Committee Member: The 37th Research Conference on Communication, Information and Internet Policy, September 2009  
Consultant to the Federal Communications Commission, 2007  
2008 TPRC Program Committee Member: The 36th Research Conference on Communication, Information and Internet Policy, September 2008

## LANGUAGES

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Fluent in English and French  
Working Knowledge of Spanish